SELECTIVE ETCHING DEVICE

Related Applications

The present application is based on and claims the benefit of U.S. provisional patent application Serial No. 60/409,480, filed September 10, 2002, the content of which is hereby incorporated by reference in its entirety.

Field of the Invention

The present invention relates to the field of mass storage devices. More particularly, this invention relates to magnetoresistive ("MR") heads and air bearing surfaces used in a data storage device.

Background of the Invention

In the manufacturing of recording heads, the removal of material from the air bearing surface is a necessary process in order to define slider sensor heights. During this material removal process, a specified level of surface planarity and roughness is required to ensure proper operation of the recording head in a hard disc drive. The state of the art process for forming sensor height and maintaining acceptable surface finish is an abrasive lapping process. However, the abrasive lapping process has inherent limitations in sensor height control therefore, alternate methods have been pursued to define the slider sensor height with improved targeting capability. While these methods have shown some promise , the impact of these methods to the degradation of head surface planarity and roughness must be controlled as a requirement for implementing the technology in production.

A recording head is a composite of materials and the material removal rates generally depend on intrinsic chemical and physical properties. The air bearing surface includes materials such as the ceramic substrate, dielectric insulating films, and materials associated with the magnetoresistive element and

writer. Some materials will have a removal rate slower than others on the air bearing surface.

What is needed is a method and apparatus that can be used to carefully control the rate of material removal in forming the stripe height dimension of individual MR elements within a row of MR elements, while simultaneously maintaining an acceptable level of planarity and roughness on the air bearing surface without being constrained by intricate and costly masking techniques. What is also needed is a method and apparatus for feedback control so that a property level of the MR element and the air bearing surface can be controlled during manufacture of the MR elements. What is also needed is a method and apparatus that is both reliable and quick, such that it can be used to produce MR elements and air bearing surfaces in large volume.

Summary of the Invention

An apparatus for use in slider fabrication having at least one exposed substrate with an air bearing surface. The apparatus has a plurality of etching devices, wherein the plurality of etching devices is made up of a physical etch component and a chemical etch component and a controller for directing the physical etch component and the chemical etch component at the air bearing surface, wherein the physical etch component and chemical etch component are combined in a manner to provide a uniform etch rate throughout the plurality of materials

Brief Description of the Drawing

FIG. 1 is an exploded view of a disc drive with a multiple disc stack.

FIG. 2 is a flow chart showing an overview of the manufacture of sliders according to the present invention.

FIG. 3 is a bottom view of a slider showing the air-bearing surface of a slider that includes a thin film write element and a magnetoresistive read element.

FIG. 4 is a schematic view of the etching device according to the present invention.

FIG. 5 is a front view of an embodiment of the present invention including a substrate selectively subject to a chemical and physical etch.

FIG. 6 is a front view of an embodiment of the present invention including a substrate selectively subject to a chemical etch and a physical etch consisting of focused ion beams.

FIG. 7 is a front view of an embodiment of the present invention including a substrate selectively subject to a chemical etch and a physical etch, the embodiment also including a shutter system.

FIG. 8 is a schematic view of a computer system.

Detailed Description

In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings, which form a part hereof, and in which are shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

The invention described in this application is useful in any semiconductor fabrication process where it may be advantageous to control the process while it is occurring. One such process is during the removal of material from a bar of sliders 126 that will be used in a disc drive 100. FIG. 1 is an exploded view of one type of disc drive 100. The disc drive 100 includes a housing or base 112, and a cover 114. The base 112 and cover 114 form a disc enclosure. Rotatably attached to the base 112 on an actuator shaft 118 is an actuator assembly 120. The actuator assembly 120 includes a comb-like structure 122 having a plurality of arms 123. Attached to the separate arms 123 on the comb 122, are load beams or load springs 124. Load beams or load springs are also referred to as suspensions. Attached at the end of each load spring 124 is a slider 126 that carries a magnetic transducer 150. The slider 126 with the transducer 150 form what is many times called the head. The slider 126 shown includes a transducer with a separate read

element and a separate write element. On the end of the actuator arm assembly 120 opposite the load springs 124 and the sliders 126 is a voice coil 128.

Attached within the base 112 is a pair of magnets 130 and 131. The pair of magnets 130 and 131, and the voice coil 128 are the key components of a voice coil motor that applies a force to the actuator assembly 120 to rotate it about the actuator shaft 118. Also mounted to the base 112 is a spindle motor. The spindle motor includes a rotating portion called the spindle hub 133. In this particular disc drive, the spindle motor is within the hub. In FIG. 1, a number of discs 134 are attached to the spindle hub 133. In other disc drives a single disc or a different number of discs may be attached to the hub. The invention described herein is equally applicable to such other disc drives.

Moving the actuator assembly 120 moves all the load springs 124. In operation, the actuator assembly 120 is moved to a park position when the disc drive is powered down. Moving the actuator to the park position causes the sliders to move to a non-data area of the disc. The non-data area is typically at the inner diameter ("ID") of the disc 134.

The present invention provides an apparatus for the formation of slider 126. The slider 126 is shown in more detail in FIG. 3. FIG. 2 shows an overview of the process 200 for forming sliders according to the present invention. The process starts with a wafer. The first step in the process is to place the wafer in a semiconducting process machine as depicted by reference numeral 210. While in the semiconducting process machine, magnetoresistive elements are formed on the wafer, as depicted by step 212. The next step is to form write heads over the MR elements, as depicted by reference numeral 214. It should be noted that a magnetic shield or shields may be placed between the magnetoresistive elements and the write heads formed. The shields may include several other layers formed by a semiconductive process. The combination of a magnetoresistive element and a write head form a transducer 150. It should also be noted that there are a multiplicity or a very large number of transducers 150 formed on a wafer. The multiplicity of MR elements 320 and write elements 360 are organized in rows on the wafer so that the wafer may be cut or sliced to form a bar that includes a row

with a plurality of transducers 150. Once all of the transducers 150 are formed, the wafer is cut or sliced to form elongated bars containing rows of transducers of MR elements, as depicted by step 216 in process 200. These elongated rows of transducers are placed in carriers and initially lapped to smooth the surface and provide a first rough removal of material, as depicted by step 218 in process 200. The next step in the present invention is to remove additional material from the surface of the rowbar via a chemical and physical etch process to further define a property level of the transducer and to achieve an acceptable level of roughness and planarity of the air bearing surface, and as depicted by step 220. A further explanation to achieve step 220 will be more fully described herein. After step 220, the remaining features on the air-bearing surface are formed, as depicted by reference number 222 of process 200. After forming the features, the rowbar is cut or diced into individual sliders 126, as depicted by reference numeral 224 and process 200.

FIG. 3 is a bottom view of rowbar 300, more specifically slider 126 which shows an air-bearing surface subsequent the lapping process 220, yet prior to the step of removing additional material 222. Slider 126 is positioned between sliders 125 and 127, which are only three sliders in a plurality of sliders present in a rowbar 200. The air-bearing surface includes a leading edge 360 and trailing edge 370, a substrate portion 380, a transducer 150 including reading portion (MR element) 320 and writer portion 325, and overcoat layer 350. Substrate portion 380 may consist of Alumina Titanium-Carbide (AlTiC), the overcoat layer 350 may consist of alumina, and the transducer portion 150 generally consists of metallic and magnetic materials.

After lapping, a second general step for removing additional material from the lapped surface rows of transducers may be used. The second general step may be to expose all the rowbars to a general ion milling process. The bars of elongated rows of transducers are placed in a vacuum chamber and ion milled. This removes material at a slower, more controlled rate than the lapping process. The surface that is ion milled is the surface that corresponds to the air bearing surface 300 of a finished slider 126 and includes the transducer 150.

FIG. 4 is a schematic view of the apparatus 400, which is used to process a system comprising of multiple materials. One such system may be a rowbar of sliders used in data storage, which is shown in FIG. 3. Apparatus 400 includes slider 405, a physical etch component or device 410 and a chemical etch component or device 420. Slider 402 is essentially a cross-sectional view of slider 126 (of rowbar 300) in FIG. 3, including substrate portion 380, transducer 150 and overcoat layer 350. Physical etch component 410 can consist of an ion beam source of a type that can be either focused or collimated, which is further shown and described in FIG. 6. The physical etch component 410 can also implement a broad ion beam, which is more fully described and shown in FIG. 7. The chemical etch component 420 can be accomplished by gas-solid reactions with gas phase atoms, molecules, radicals, and/or ions. The chemical etch component 420 forms reaction byproducts that are either volatile or nonvolatile. Under certain conditions, materials in slider 402 may have a high physical sputter rate but low chemical etch rate, while other materials in slider 405 may have high chemical etch rates but low physical sputter rates. By adjusting the chemical and physical nature of the etching process, etch rate difference across several materials are reduced, thereby achieving air bearing surface requirements or desired property levels (such as planarity, cleanliness, pole tip characteristics and roughness), and the sensor definition (resistivity) requirements in one efficient and accurate processing step.

One example in which apparatus 400 could be implemented is as follows: Chemical etch component 420 provides a chemical flood gas locally to the air bearing surface. The gas may be comprised of, but is not limited to, O_2, F_2, orXeF_2. Simultaneously, the physical etch component 410 etches the air bearing surface. The physical etch component 410 may comprise of, but is not limited to, accelerated ion species such as Ar^+ and Xe^+. The physical etch component 410 implements an acceleration energy approximately on the order of 100eV to 5000eV. The balance between the chemical and physical processes can be used to modify the etch rates of at least two of the constituent materials at the air bearing surface. In one example, two materials make up the substrate portion 380 of AlTiC. Under physically dominated etching, TiC will etch slower than Al_2O_3. By using a reactive

flood gas, the TiC phase etch rate can be accelerated through a chemical means along with optimized partial pressure and/or flow rate of the flood gas. This concept is also applicable to the other materials on the air bearing surface (dielectrics, reader materials, writer materials) Material etch rates via chemically-assisted physical sputtering can be either enhanced or impeded relative to the etch rate from physical sputtering alone.

Chemical etch component 420 can also be an ionized reactive gas in which case both chemical and physical components are combined in a single source 420. The extent of physical etching of the source 420 is varied by means of variable ion acceleration energy over a range of approximately 100 eV to 5000 eV. The chemical etch component of the source 420 is varied by the choice of reactive gas(es) and their respective partial pressure(s). The process gas may be comprised of, but not limited to, SF_6, CF_4, O_2. This reactive ion source can still be used in combination with the physical etch component 410 consisting of accelerated ion species such as Ar^+ and Xe^+ to further extend the range of physical etch control by varying the ion acceleration energy over the range of approximately 100 eV to 5000 eV. In regard to the substrate portion 380, comprised of AlTiC, a fluorine containing etch gas could be used to chemically-assist the etch process of the constituent TiC phase relative to the constituent Al_2O_3 phase so that the two phases achieve an equalization in etch rates. In a similar manner, the etch rates of other materials on the air bearing surface can be manipulated in order to achieve more similar etch rates.

FIG. 5 is a schematic view of the apparatus 500 which is one example of how to implement apparatus 400 in order to remove material from rowbar 550 that includes a plurality of individual MR elements and write elements. The apparatus 500 includes a chemical etch component 510, a physical etch component 520 and a carrier 512 situated within a vacuum chamber 505. The carrier element 512 includes a stage 515. The stage 515 moves with respect to the carrier 512. Also included are control electronics 530. The control electronics 530 control the chemical and physical etch components 510 and 520, as well as the stage 512. The chemical and physical etch components 510 and 520 are located within the vacuum

chamber 505 to facilitate the fabrication of electrical devices in which the electrical performance depends upon the physical geometry of the device structure.

The process cycle, as described above in regard to apparatus 400, generally includes chemically and physically etching based on known parameters for a predetermined amount of time. Parameters may include the etch rate of various materials. The control electronics 530 control the amount of time spent in each area of the rowbar 550. Next, the etching process is stopped upon reaching a desired property level. Then, stage 515 is moved in order to redirect the etching devices 510 and 520 so that they are positioned on a new area of rowbar 300.

FIG. 6 is a schematic view of the apparatus 600 which is another example of how to implement apparatus 400 in order to remove material from rowbar 550 that includes a plurality of material with varying etch rates. The apparatus 600 includes a chemical etch component 610, a physical etch component 620 and a carrier 612. The carrier element 612 includes a stage 615. The stage 615 moves with respect to the carrier 612. Also included are control electronics 630. The control electronics 630 control the chemical and physical etch components 610 and 620, as well as the stage 612, and an electrical probe system which connects a probe or probes to individual transducers 152 on rowbar 650. The electrical probes are shown or depicted by signal carrier 660, which carries a signal related to a parameter being measured as the chemical and physical etch components 510 and 520 remove material from the air bearing surface of the rowbar 650. The chemical and physical etch components 610 and 620 are combined within the vacuum chamber 605 to facilitate the fabrication of electrical devices in which the electrical performance depends upon the physical geometry of the device structure. Such a device is an MR element 152. The resistivity of the MR element depends upon the stripe height of the MR element. The signal produced by the electrical probe system situated at the first area is fed back to the control electronics 630. The signal from the probe electronics act as a feedback signal in a control loop and enables accurate targeting or specification of the magnitude of a desired electrical property or properties in the first area. As soon as the desired value of the properties of the first area is reached, the control electronics 630 stop the etching or removal of further

material from the first area or the first particular device, such as an MR element 152. Generally, the control electronics 630 will blank the etch components to the side where it will not remove material from other areas or another element or device on the rowbar 650. The etch components are deflected until the control electronics move the stage 615 with respect to the carrier 612 so that second area will be positioned directly below the etch components. The process of removal of material using the chemical and physical etch components 610 and 620 is then repeated with the next area of the rowbar.

The process cycle, as described above in regard to apparatus 400, generally includes chemically and physically etching until a desired property level of the selected area of the rowbar is reached. This is done partially by engaging the electrical probe 660 to one of the pads of the transducer 152, then etching the transducer to an electrical end point where a particular electrical property being measured by the probe is at a desired level. The next step is to stop the etch upon reaching the end point and then disconnect the probe to devise a contact and then move the stage 615 or redirect the etching components 610 and 620 so that it is positioned on a new area which includes a new MR element or device to which the electrical probe 660 has been attached.

One skilled in the art will appreciate that certain aspects of Figs. 5 and 6 may be altered without departing from the present invention. For instance, the chemical and physical etch devices 510 and 520 may be positioned differently in relation to the rowbar 750 in order to optimize certain etching angles. Also, the number of carriers, stages, probes, etch components, may be changed and still obtain the advantages realized by the present invention.

FIG. 7 is a schematic view of another apparatus 700 for selectively removing material from devices as contemplated by apparatus 400. Apparatus 700 is similar in operation to the apparatus 600 shown in FIG. 6. Rather than describe the entire apparatus in detail, for the sake of clarity, the differences between the apparatus 700 and the apparatus 600 will be discussed. Apparatus 700 includes shutter system 780 (including multiple shutters 790) located between chemical and physical etch components 710 and 720. Shutter system 780 is used to cover some or

all of the transducer 152. Shutter system 700 includes a plurality of shutters 790 that can be actuated or moved between a position where a portion of the rowbar is covered and a portion of the rowbar that is not covered. Controller 730 is electrically attached to the shutter system 780. When the desired property level is reached for a particular area of the rowbar 750, the controller 730 sends a signal to an actuator (not shown) that moves shutter 790 over the particular area of the rowbar so as to minimize or substantially halt further removal of material from that area. More specifically, etching continues while the various shutters 790 are moved from an uncovered position to a covered position. Each shutter 780 acts like a mask in that it shields or substantially shields the portion of the rowbar from this etching process.

One skilled in the art will appreciate that certain aspects of Fig. 7 may be altered without departing from the present invention. For instance, the chemical and physical etch devices 510 and 520 may be positioned differently in relation to the shutter system 780 and rowbar 750 in order to optimize certain etching angles. Also, the number of shutters 780, carriers 712, stages 715, probes 760, etch components 710 and 720, may be changed and still obtain the advantages realized by the present invention.

FIG. 8 is a schematic view of a computer system 800 used as part of the control electronics. The computer system 800 may also be called an electronic system or an information handling system and includes a central processing unit, a memory and a system bus. The information handling system includes a central processing unit 804, a random access memory 832, and a system bus 830 for communicatively coupling the central processing unit 804 and the random access memory 832. The information handling system 802 may also include an input/output bus 810 and several devices peripheral devices, such as 812, 814, 816, 818, 820, and 822 may be attached to the input output bus 810. Peripheral devices may include hard disc drives, magneto-optical drives, floppy disc drives, monitors, keyboards and other such peripherals. Any type of disc drive may use the slider having the surface treatment discussed above. The computer system is programmable and acts in response to program instructions. A software program is

loaded onto the computer system 800. The software program provides control functions which a user can use to select and implement the various processes described in the above paragraphs.